6 December 1967

Materiel Test Procedure 5-1-026
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
BACKGROUND DOCUMENT

RANGE INSTRUMENTATION LAYOUT

1. INTRODUCTION

Range instrumentation comprises the essential, specific organs of range testing. With devices and systems analogous in many ways to the human nervous system, brain, or sensory system, instrumentation determines the practical boundaries within which a test range is confined, it circumscribes limits about the performance capabilities, capacity, scope, efficiency, and even the vitality of the range.

Range instrumentation measures trajectories and internal performance of test objects, controls the flight of targets and boosters, correlates observations with range time, and processes the data gathered. Instrumentation may be special purpose or general purpose. A single instrument may suffice to gather all the data needed for a specific test, whereas a complex of many instruments may be essential for another. Representative single place instruments are the theodolites, telescopes, cameras, and tracking radars. There are numerous multi-station configurations of electronic control and data processing instruments, as well. The data processing instruments include computers, decommutators, plotting boards and display devices, communication links, and command control consoles. There are field instruments for reception of telemetry from drones and surveillance; optical instruments for tracking and photography; telecommunications; and timing equipment.

Composition of range instrumentation varies with the type of range. An aeroballistic range, for example, needs trajectory measurement instrumentation primarily; meanwhile, an electronic proving ground emphasizes reception, detection, and correlation of simulated operational signals in the presence of expected forms of operational interference.

Instrumental resources include, also, innumerable laboratory services for measurement and controls. The full spectrum of test instrumentation serves major facilities, such as wind tunnels, dynamometers, and the other well known means for static testing, which are found even at laboratories of missile test ranges.

Well established range instrumentation can be based upon electronic, chemical, nuclear, thermodynamic, ceramic, electrical, mechanical, or optical technologies, and frequently a combination of several of them. Many different types of scientific instruments are used to measure all kinds of physical dimensions and experimental parameters, such as temperature, humidity, pressure, strain, and vibration. They also control the angles subtended between a test object and known reference points, establish relative separation distances between a test object and known reference points, establish relative separation distances between airborne vehicles, or regulate their speed and acceleration;

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others are used to secure photographic records of dynamic behavior.

2. FUNCTION OF RANGE INSTRUMENTATION

The basic functions of range instrumentation can be divided into two categories; observational and control. Observational measurements largely consist of recording and processing of documentary information and engineering data, while control functions generally cover the control of test operations, safety and security, navigation and position, and simulation or control of test conditions.

2.1 Observations Within Test Object

These objects are usually instrumented in such a way that internal functions can be monitored. For example the information telemetered from a missile while it is in flight.

2.2 Observations external to the test object

These are usually measurements taken of the environment in which the test item is operating and data on the externally observed performance of the test item itself.

2.3 Basic Measurements

Tests conducted at instrumented ranges are usually designed to fulfill criteria. In the case of missile systems these measurements would include measurements of the trajectory of the missile and predictions of attitude and acceleration, and monitoring the internal function of the guidance system. Tests are also conducted to determine system response to a particular stimulus, and to determine the ability of the item to fulfill its specified criteria.

2.3.1 Measurement Process

The process by which these measurements are gathered usually include an analysis of the requirements for information by the test engineer. This analysis usually includes provisions for the planning of measurement approach, methods, scheduling, and reporting, the selection of available measurement devices, systems, instruments, and skills. It should also include engineering and design of any special instrumentation required, and provision for the assembly, test, installation, trial, and calibration of the measurement systems. Instructions for the acquisition, preliminary preparation, and reduction of extracted data into meaningful terms should also be included.

2.4 Processing of Experimental Data

The handling of data acquired during the flight of a missile requires that provision be made first of all for transmission of the data from the item under test to the data processing equipment. The method of transmission can be by land-line or radio and the form of modulation can be of any form suitable to

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convey the desired information, such as Amplitude Modulation or Frequency Modulation. The information received from the item under test must be stored in some manner. The usual methods being magnetic tape or magnetic core storage. Data may also be gathered by photographic means and processed by the usual methods of film processing.

In addition data obtained during a test usually needs to be converted from its original form to a form on which an analysis can be performed. This is done when an original analog signal from a transducer is quantified and transformed to a coded pulse train for transmission and storage. This train is then transformed and optimized to put it into a form suitable for reduction on a digital computer and to remove random data errors. After appropriate computation the data is then reconverted to analog form for final documentation.

2.5 Telecommunications System

This term generally refers to the range communication network which supports instrumentation, timing, command, control, status, data transmission, and voice communications.

2.6 Time Correlation of Events and Data

At most ranges this is done by the use of a sequentially coded timing pulse train transmitted over the range telecommunications system to various instrumentation and operation sites. The functions of these sites can be controlled by coded commands transmitted in synchronization with the timing train.

2.7 Space Correlation of Events and Position

The various sites on a range are usually located with respect to a common coordinate system with accuracy of greater than one part in one million. The respective measurements taken of the test item from these sites can then be used to determine the location and space position of events during the conduct of a given test.

2.8 Control of Test Operations

The range instrumentation is also used to control the conduct of a test. This is accomplished by utilizing the timing functions of the range to insure that the test will begin and end at predetermined times and control the operation of the proper instrumentation and test functions in accordance with the sequence of test conduct as specified by the testing agency. It is also used in the case of missile systems to provide trajectory plots to determine if the missile will stay within the safety boundaries of the range. If it is determined that it will not, a radio command is sent to a destruct mechanism and the test terminated.

3. QUALITIES OF RANGE INSTRUMENTATION

Testing Range Instruments are usually rated by their accuracy, precision, and repeatability, the accessibility and simplicity of the data they produce and their reliability and stability. They are also evaluated by their data handling ability, their adaptability to changing test requirements, and the amount of geographic coverage they are capable of furnishing.

These are the qualities that are evaluated along with the mobility, availability, versatility and compatibility, when determining the instrumentative layout of a test range.

4. EXAMPLE OF RANGE INSTRUMENTATION

An example of how this might be done is shown on the maps of White Sands Missile Range included in this MTP. These maps show how the problem of locating various tracking, radar, optical, and communications sites was solved there, in order to accomplish integrated and total test instrumentation and data handling capability throughout the geographic area covered by the range.

The first map shows the location of the DOVAP Sites at White Sands. DOVAP (Doppler, Velocity, and Position System) consists of a fixed reference transmitters, a transponder in the missile, and a complex of fixed receiving stations.

Space position of the missile is computed from audio-frequency data recorded, at three or more fixed receiving stations, on photographic and magnetic tape recorders. The information normally obtained by solving for the intersections of three ellipsoids of revolution includes three co-ordinates of space position and velocity derived from position differentials. A counter circuit responds to each Doppler beat cycle. By electronic integration of the Doppler beat cycles, over measured time intervals, DOVAP data can be converted to measurements of changes of total path length. Each transmitter receiver pair produces only scalar quantities. The locus of measured scalar data is an ellipsoid of revolution having one of its foci at the transmitter and the other at the receiver.

Thus by using one transmitter in conjunction with three receivers the location of the object in question can be determined from the intersection of the three ellipsoids of revolution.

Radial velocity of the test object can be obtained directly from the doppler shift. At White Sands the system is set up so that the tracked object can be transferred from one tracking system to the other with as many as twenty receiver stations in operation at one time.

The radar chain systems at WSMR are linked by telecommunication subsystems, are synchronized, and are sited sufficiently close together for successive radars to lock-on the missile before the preceding radar loses it. The radar chain also delivers real-time acquisition data with which long focal-length optical instruments may be trained on the missile even when it is temporarily obscured by clouds.

Radar chain systems feature auxiliary components including electron plotting boards, analog computers, recorders, analog-to-digital converters,

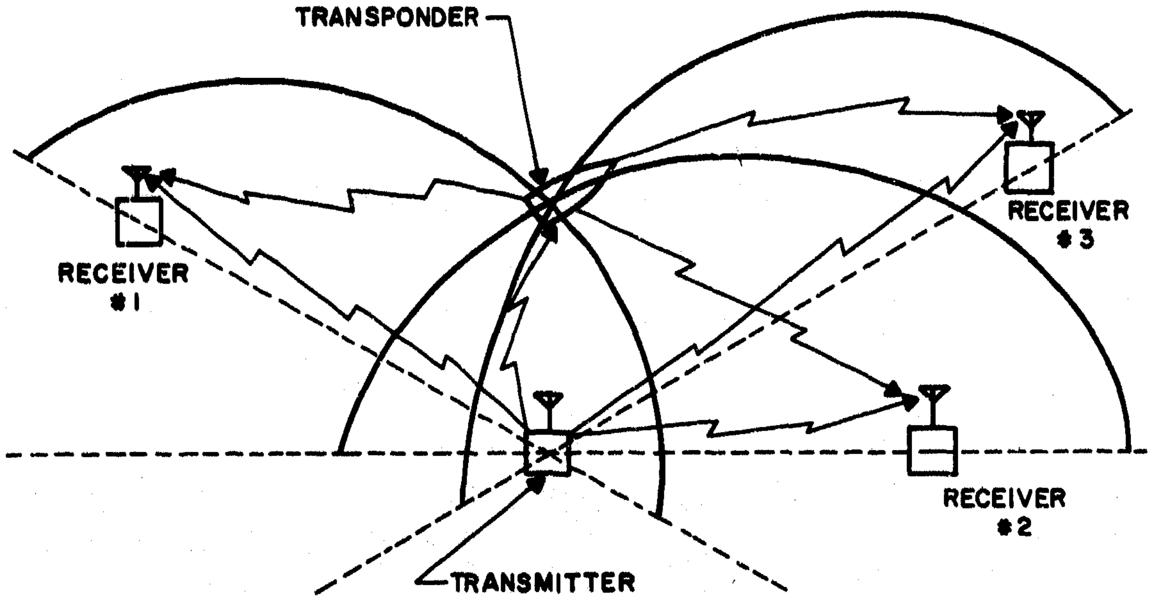


Figure 1. Basic DOVAP System

and communication and data transmission equipment. With the analog computers, ground track of the missile is developed from radar range, elevation angle, and bearing angle. The ground track automatically is plotted in real time. Plotting mechanism delays are sufficiently short as to be ignored or easily accounted for by the human observer.

At the radar station located nearest the launcher, the missile's initial trajectory is converted to digital form, transmitted to the control center, and then relayed to other radars in the chain. As the flight proceeds, successive radars may take command of the chain, as dictated by geometrical and other range conditions.

The optimum tracking radar during the flight is selected by means of a computer. Performance of each radar, status, geometry, and other pertinent factors are considered by the commander of the chain on the basis of status board display.

Much of the information needed to improve the design and perfect the operation of missiles, rockets, projectiles, or high-performance aircraft is obtained with photo-optical instruments.

The data obtained is usually classified in three principal categories:

1. Documentary - historical film records of conditions, procedures, progress, and important events primarily valuable for exposition, review, and training purposes.
2. Metric Analysis - dimensionally controlled film records of the time-space relationships which describe the motion of vehicles with respect to celestial, geographical, and optical co-ordinates; from them numerical values may be obtained for computations of position-time history, impact prediction and location, evaluation of performance, and progression from qualitative to quantitative knowledge.
3. Engineering Analysis - sequential film records of technical or dynamic phenomena so referenced by time and space coordinates that qualitative answers may be derived from them.

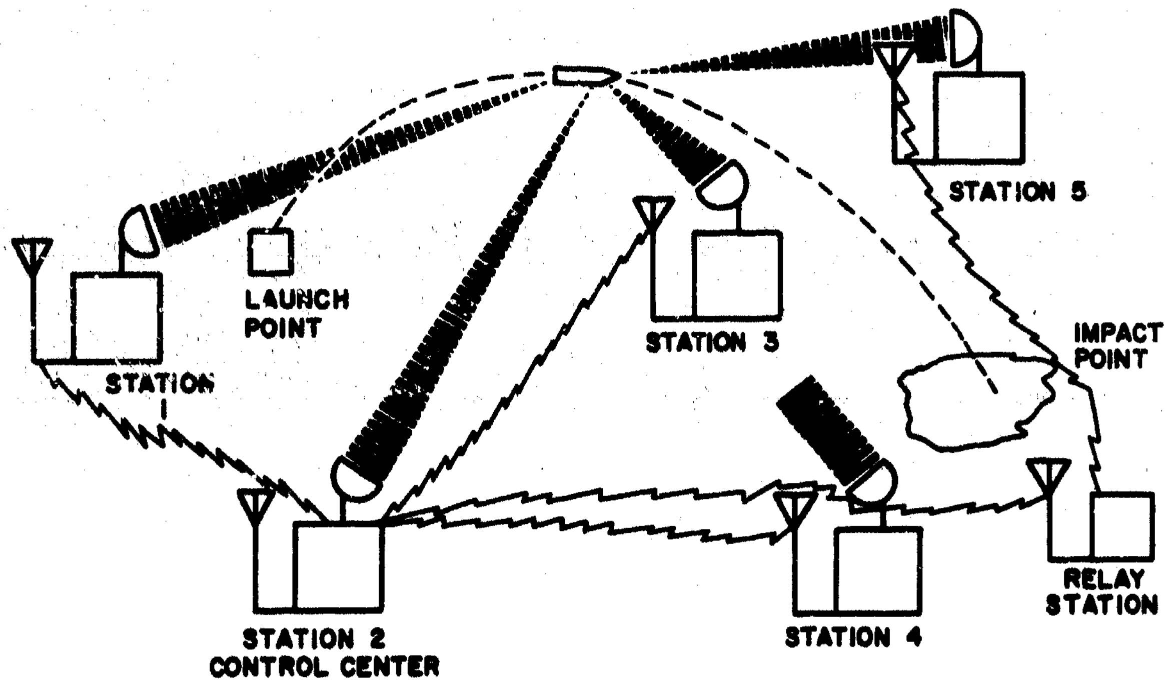
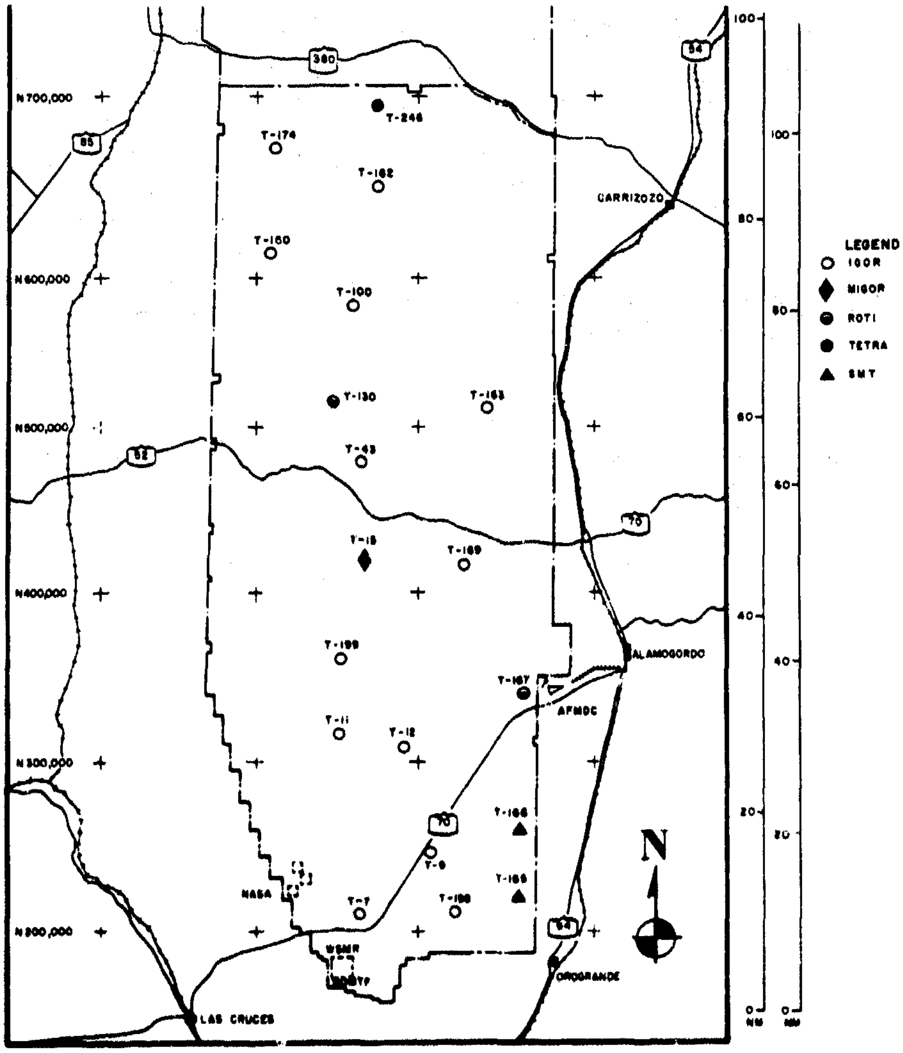


Figure 2. Method of Radar Chain Tracking of Missiles.

TELESCOPE INSTRUMENTATION SYSTEM

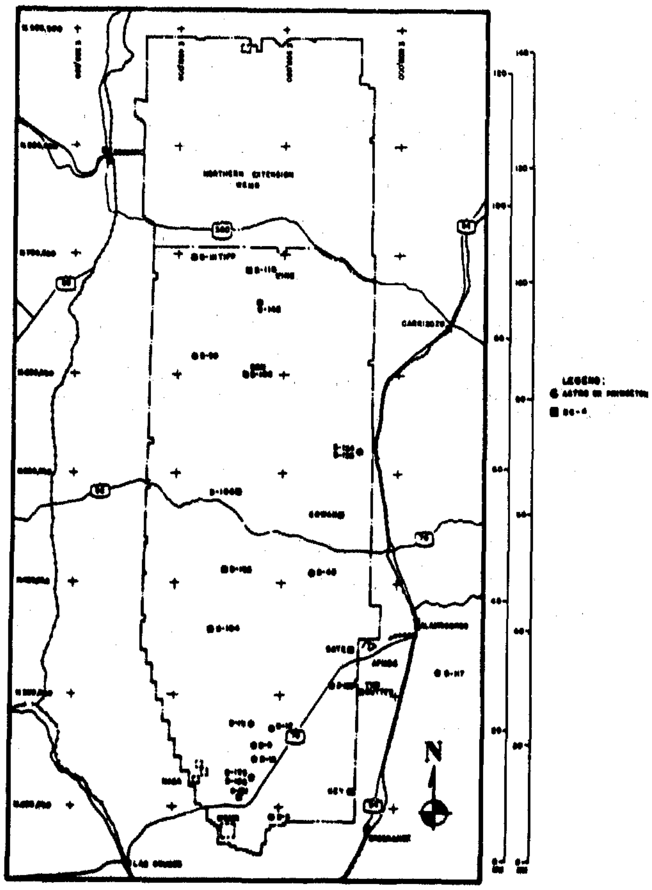
A tracking telescope is a long focal length optical recording instrument. The tracking telescope system's primary purpose is to record qualitative mission data. In addition, this system supplements range metric instrumentation by providing attitude, miss-distance, roll, engineering sequential and documentary data. Portions of the Tracking Telescope System are mobile, providing greater flexibility in complying to operation requirements on and off the Range proper. Ten tracking telescopes with focal lengths ranging from two to five hundred inches and capable of recording with 35 and 70 mm cameras are available. Tracking telescope system data are particularly valuable for diagnostic analysis of target malfunctions. Project personnel utilize the film for sequential information and engineering analysis.

There are 54 telescopes on and off range. These are 15 fixed IGOR's, 3 fixed MIGOR's, 4 mobile TETRA's, 1 mobile MFLMTT, 2 fixed ROTI's, 21 mobile M45-55's, 1 fixed T-4, 4 mobile Cine Sextants, and 3 MT-1's.



BALLISTIC CAMERA INSTRUMENTATION SYSTEM

Ballistic Cameras are rigidly mounted, wide field, fixed plate cameras used to obtain quantitative data for computation of ballistic trajectories and calibration of other instruments, and for meeting stringent position measurement requirements that cannot be met by other measurement systems. There are 36 Ballistic Cameras on the Range. Twelve are BC-4's (fixed), 18 are Astro MK II (portable) and six are Princeton (portable). These cameras are the most accurate position measuring system available.



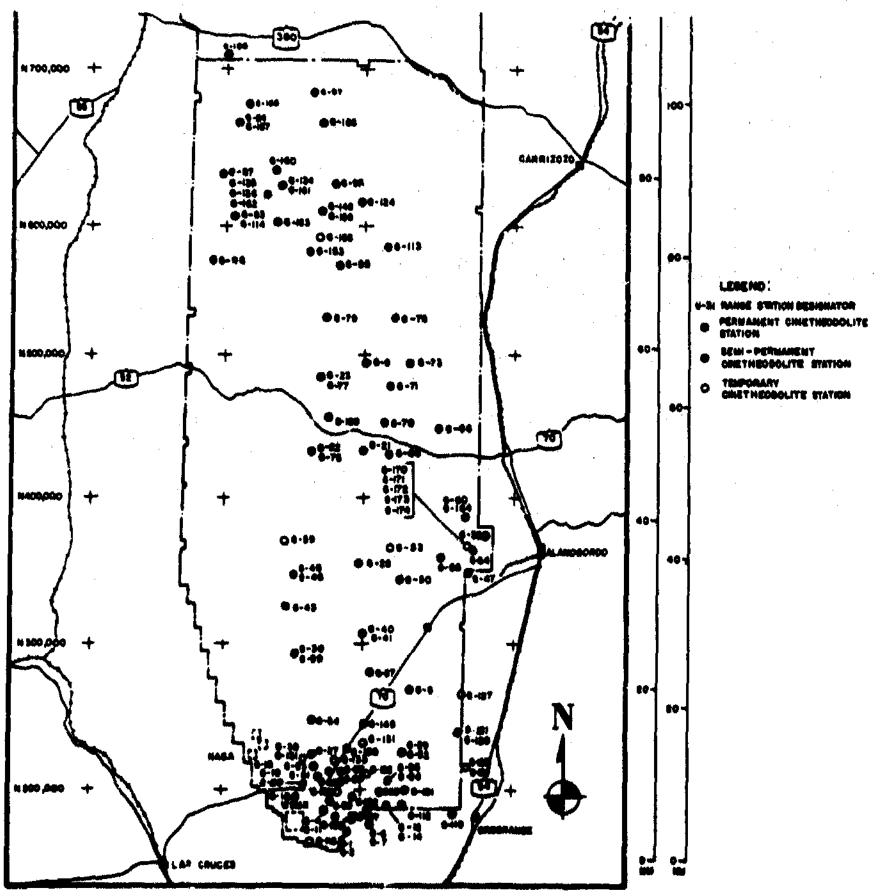
BALLISTIC CAMERA CHARACTERISTICS AND CAPABILITIES

CHARACTERISTICS & CAPABILITIES	BC-4	ASTRO MK II	ASTRO MK I	PRINCETON
Format size(inches)	7-$\frac{1}{4}$ x 7-$\frac{1}{4}$	8 x 10	8 x 10	8 x 10
Lens focal length	115mm (2-infrared, 2-visible light) 210mm (2-infrared, 2-visible light)	7-12 in.	7 in.	12 in.
Samples/sec	2-20 or dependent on beacon rate	Depends on light source	Depends on light source	Depends on light source
Data reduction time (weeks)	3-4	3-4	3-4	3-4
Portability	Fixed	Portable	Portable	Portable
Number	8	12	6	6
Age (years)	7	9	11	20
Accuracy, instrument (sec of arc)	2-5	2-10	2-10	2-10

CINETHEODOLITE INSTRUMENTATION SYSTEM

Cinetheodolites are optical tracking instruments designed to permit angular position recording of the pointing axis from the instrument to the target. The vehicle image is recorded on photographic film with azimuth and elevation angular data. Simultaneous operation of two or more cinetheodolites permits the derivation of position, velocity, acceleration, and attitude data. Cinetheodolites can be employed on most daytime operations with acceptable atmospheric conditions.

There are 86 35mm cinetheodolites on the Range, located at permanent, semi-permanent and temporary stations. Twenty Askania Cinetheodolites have been incorporated into Mobile Cinetheodolite Mounts (MCM). Mobility of the Askania permits maximum flexibility in geographical coverage at minimum capital investment. The present system includes 40 KTH 53's plus one modified unit, five KTH 58's plus one modified KTH 58E, seven BRL-NGF's, 15 Contraves, four GTK 40's and 13 KTH 41's. 25 of these have aided tracking which increases the tracking rates. The focal lengths on the cinetheodolite optics range from 24" to 120".



RADAR INSTRUMENTATION

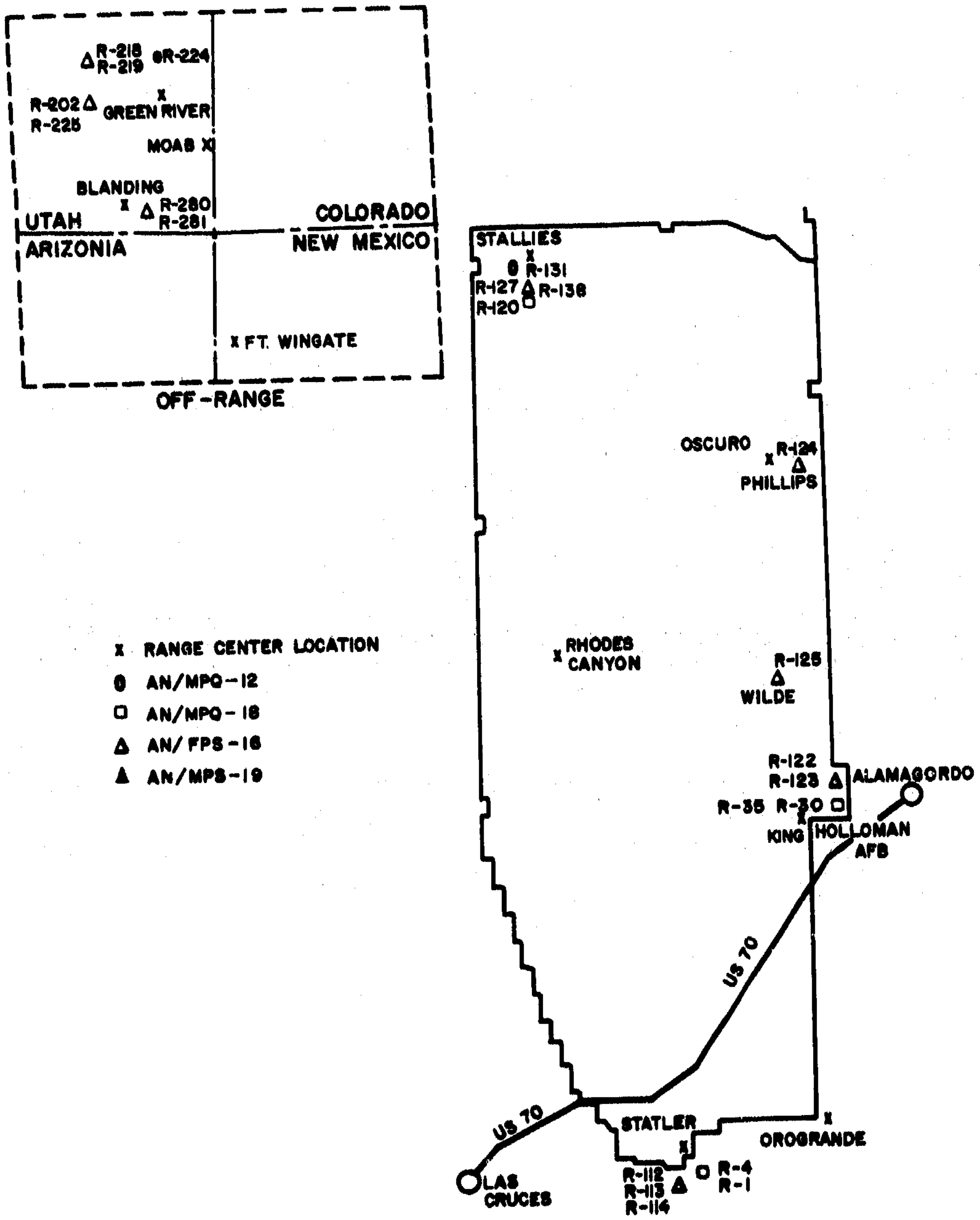
The AN/FPS-16 (fixed) and the AN/MPS-25 (transportable) tracking systems are high-precision, C-band, pulse radars operating in either skin or beacon track modes. There are eleven AN/FPS-16's and two AN/MPS-25's at WSMR. These radars provide data for real time and post test data reductions, real-time trajectory data to the Missile Flight Safety Officer, trajectory and special measurement data, acquisition data to other data collection systems, and vectoring data for drones and aircraft.

Nine of the permanent AN/FPS-16 sites are located within the WSMR boundary, two are located off-Range at the Green River, Utah launch facility (R-218, R-219), and the two mobile AN/MPS-25's are currently used to support four off-Range launch areas (Green River, Utah; Blanding, Utah; Ft. Wingate, New Mexico; and Datil, New Mexico.)

SECONDARY RADAR SUPPORT

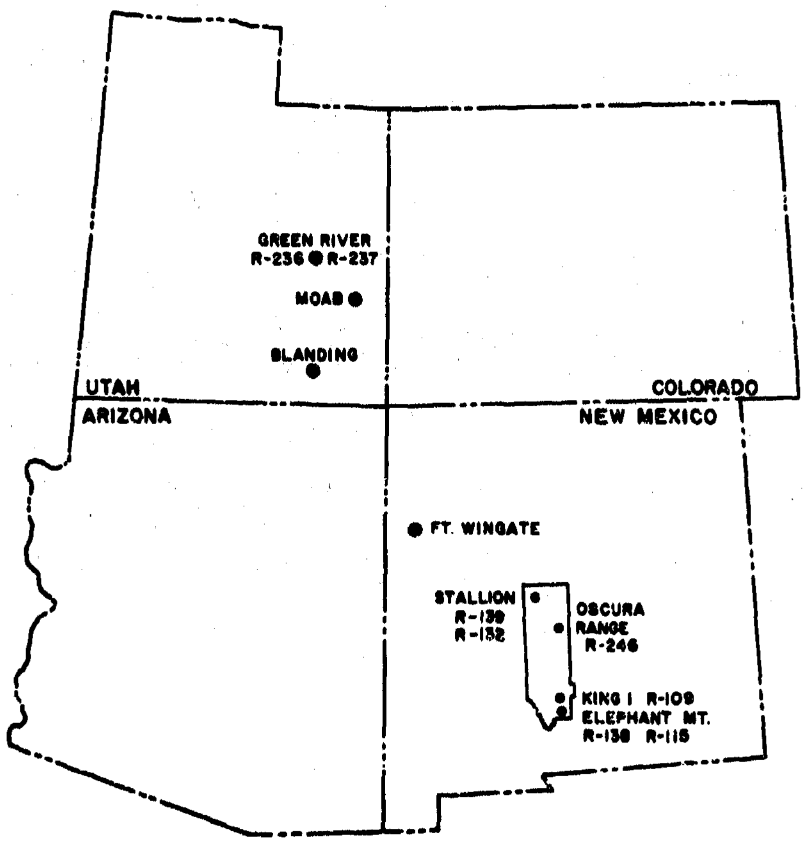
Secondary Radar Support is provided by S- or X- band, coincally-scanned tracking radars (AN/MPQ-12, five permanent - three mobile; AN MPQ-18, five permanent - no mobile; AN/MPS-19, one permanent - two mobile). Primary use of these radars is to provide low accuracy measurements to Range users and acquisition data for FPS-16 radars and optical instruments. Associated with these radars (and the FPS-16 radars) is a radar chain system that receives, converts position coordinates, and distributes acquisition data which aids in reducing the workload of the AN FPS-16 radars on missions which have less severe tracking requirements.

INSTRUMENTATION RADAR



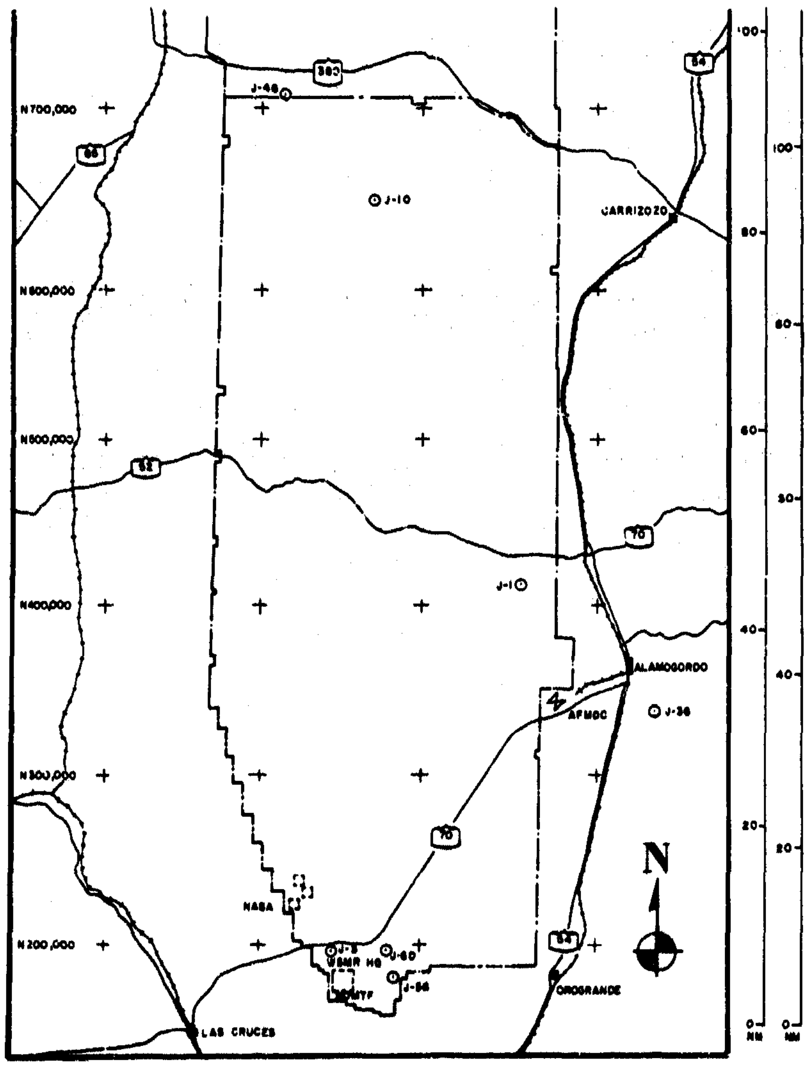
SURVEILLANCE RADARS

Surveillance radars are located on- and off-Range to assure aircraft safety and detect unauthorized penetrations of the air space. A permanent installation, operating at Elephant Mountain in the southeast corner of the Range, uses an AN/FPS-4 height finder and an AN/FPS-8 search radar. A second permanent installation, operating at Stallion Site in the northwest corner of the Range, uses an AN/FPS-6 height finder and an AN/FPS-33 search radar. One fixed M-33 search radar operates at King I and one at Oscura Range Center. There are two mobile M-33 radars at Green River, Utah. In addition, the mobile M-33 radars are used for local coverage on an interim basis at Fort Wingate, New Mexico; Moab, Utah; and Blanding, Utah.



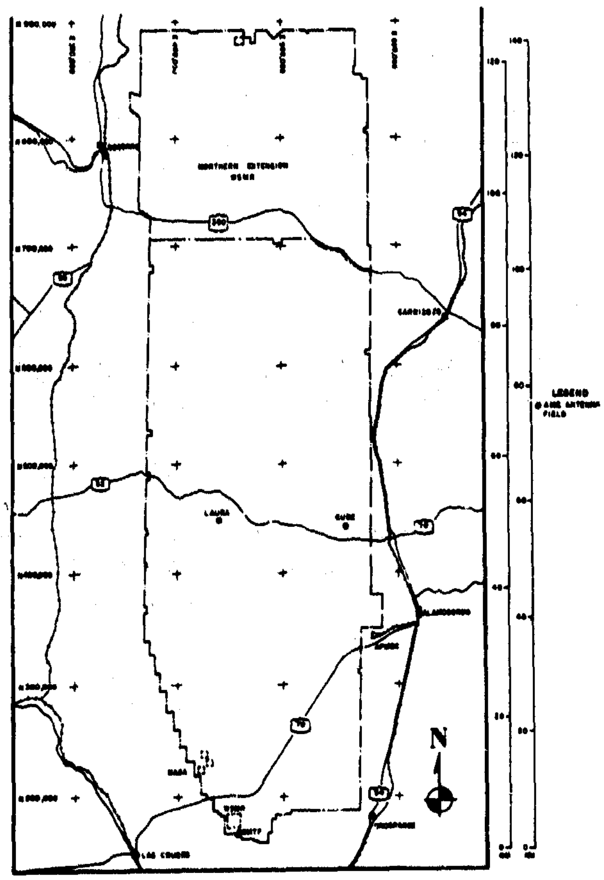
TELEMETRY STATIONS

The Telemetry Receiving and Relay System Complex consists of 26 acquisition and relay stations and transportable telemetry checkout units (10 fixed and 16 mobile; 8 on-Range and 18 off-Range). Fixed stations are located to provide telemetry support within a specific geographical area and are supplemented by mobile units for added coverage where needed. The present telemetry complex provides adequate coverage for a maximum of six VHF carriers or a single UHF carrier. Real-time reduction and computer analysis of selected telemetry data channels are available for a maximum of twelve channels, selected from a maximum of two VHF carriers. Off-Range coverage is available only on a receive, record, relay, and local display basis by means of transportable stations.



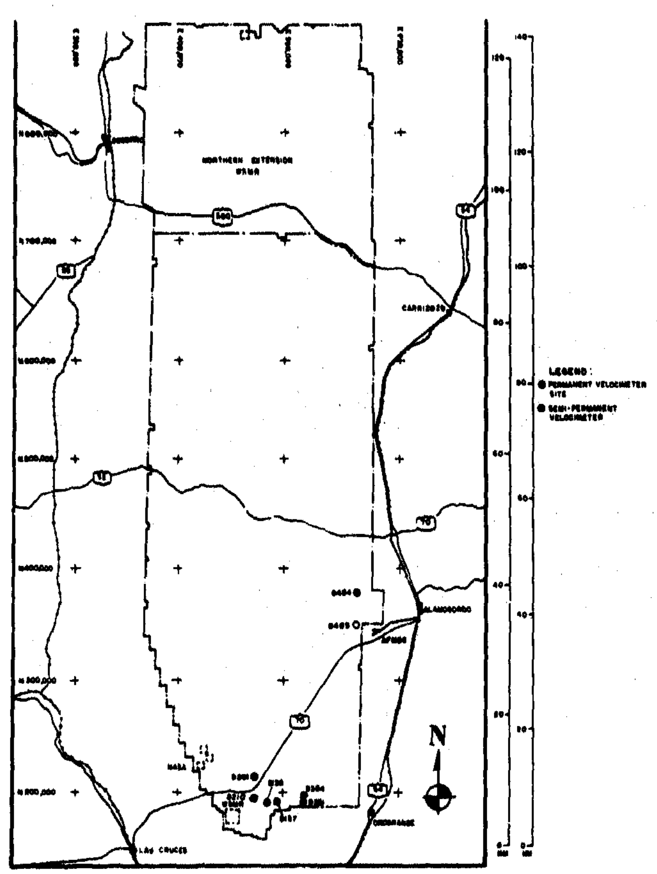
AME INSTRUMENTATION SYSTEM

There are two Angle Measuring Equipment Stations, located at Laura and Cube Sites and three calibration points located at Salinas Peak, Alamo Lookout and Rose Site. The system range is 400 miles (limited by Airborne signal source). The AME as now designed tracks a VHF telemetry airborne transmitter. VHF will not be available after 1970, and calculations show that the system is not effective in UHF area. Therefore, the system will be retired when VHF telemetry is abandoned. The AME is used for safety, quick-look, and measurement analysis.



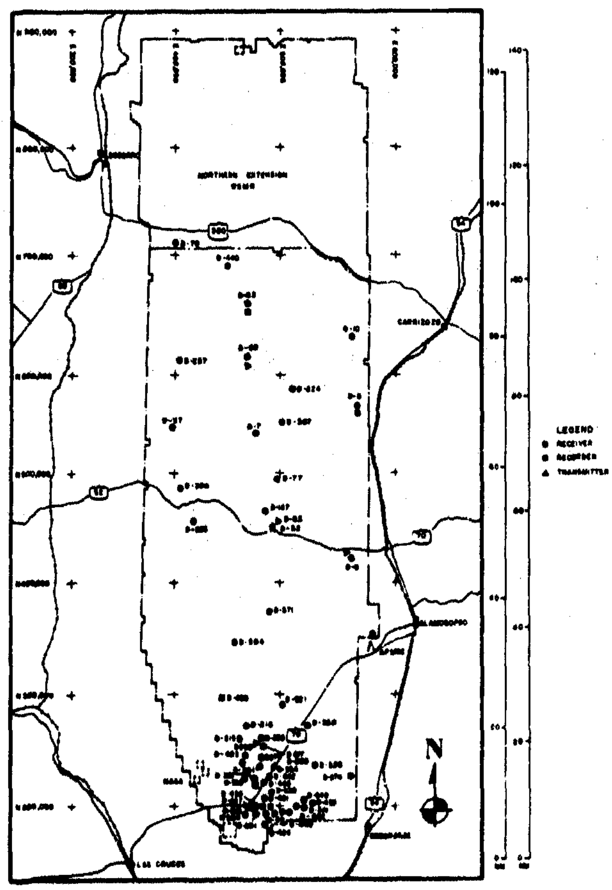
VELOCIMETER INSTRUMENTATION SYSTEM

There are seven Velocimeter Systems consisting of a microwave continuous wave transmitter and receiver. A transmitter, normally located directly behind the missile launcher, illuminates the missile. The reflected signal is compared to the transmitted carrier, and the Doppler frequency is extracted at the receiver. Radial velocity of the target is then determined from the Doppler frequency. The velocimeters are modified Hawk illuminators. The instruments are mobile, and are normally located at the sites shown below.



DOVAP INSTRUMENTATION SYSTEM

The Doppler Velocity and Position (DOVAP) System consists of a ground reference transmitter, a frequency doubling missile transponder, and a number of remote ground receivers. There are six (two mobile and four fixed) transmitters, 98 (70 mobile and 28 fixed) receivers, and 13 (nine mobile and four fixed) receiver/recorders in the present system. The DOVAP System is used for measurement analysis. It is less complex to operate than other trajectory data systems and produces very precise data. The system requires an on-board transponder and antenna, and can make Doppler measurements to altitudes of 60 miles at any point over the Range.



ELECTRONIC SKY SCREEN EQUIPMENT (ELSSE)

WSMR has four ELSSE Systems, each of which is mobile to allow flexibility in placement in the desired launcher area. Each unit consists of a single baseline, a dual channel receiver, error sensing unit, a mechanical servo, and a strip chart recorder. The system furnishes the deviation angle information from a programmed trajectory in real time for flight safety.

FIXED CAMERAS

Fixed cameras are utilized to photograph portions of a missile flight without tracking the vehicle. Data are recorded by pointing and firmly fixing the camera axis so that the field of coverage will include trajectory segments of interest during operation. In launch phases, data such as angular velocity and acceleration in roll, pitch and yaw planes, and the orientation and attitude of the vehicle are recorded. Engineering sequential information, which is vital when mission malfunctions occur during launch phases, is provided by fixed cameras. There are 454 fixed cameras in use on the Range. They are located at launch complexes, impact areas and at strategic points along the vehicle's trajectory.

GEODETIC SYSTEM

The Geodetic System at WSMR consists of many subsystems composed of Control Networks, Instrumentation Location and Orientation Surveys, Coordinate Systems, and Survey Datums. Locally surveyed triangulation stations are primarily located geographically where Range activities are the heaviest and/or where U. S. Coast & Geodetic Survey (USC&GS) sites are scarce or nonexistent. The Geodetic System locates and orients Range Launch points, impact points, and instrument sites/stations with respect to the reference geoid and local coordinate systems. Services are provided by a USC&GS team at WSMR. The Geodetic System furnishes the most accurate on-Range relative position information with the shortest lead time and least expenditure of funds.

MISS-DISTANCE INDICATOR (MDI)

The active Miss-Distance Indicator, AN/USQ 11 (XN-2) operates on the Doppler principle and determines the relative velocity between the target drone and the missile. The system requires a telemetry transmitter in the missile, a transponder in the target, and a ground station. There are three ground stations located at "B" Station, Two Buttes, and Mockingbird Gap.

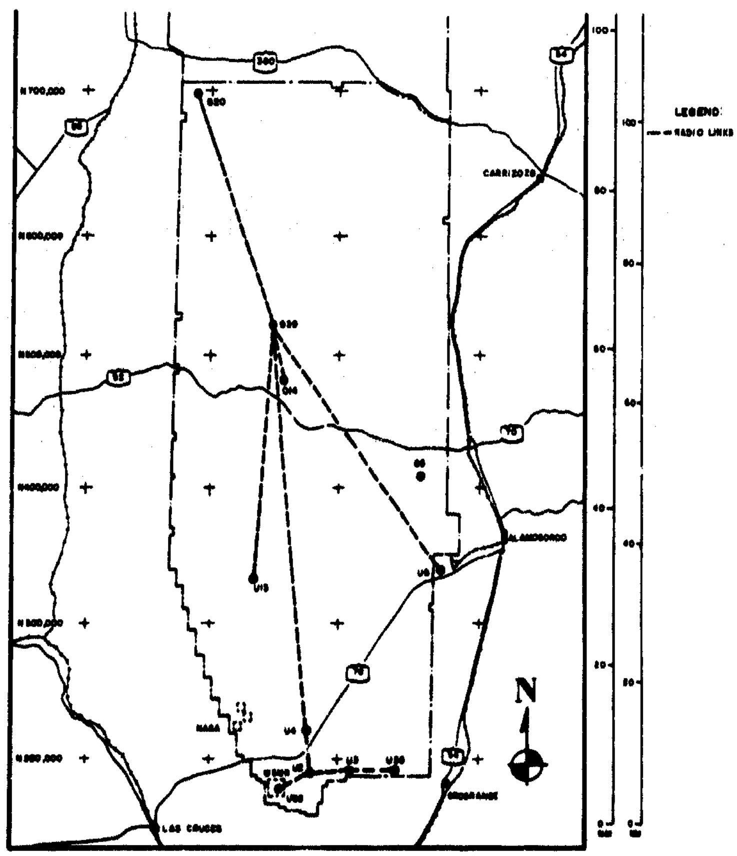
PHOTO-OPTICAL DEVELOPERS AND PRINTERS

WSMR maintains a film processing laboratory to process film and paper. The photographic processing system consists of automatic and manual machines which process film to provide raw data on black and white, and color records. Equipment consists of 10 photographic contact printers (5 for both black and white and color, 3 color only, 2 black and white only) ranging from 16mm to 70mm, six reduction and/or enlarging printers (4 black and white and 2 color), four immersion (color) photographic processors, seven spray (black and white) photographic processors, and one roller transport (black and white) photographic processor.

INSTRUMENTATION TIMING

There are twenty-five Timing stations; eight in the South Range and seventeen in the North Range. The Timing System provides the instrumentation systems with fixed timing rates, elapsed time and control signals. These signals are combined into pulsed signals and modulated carrier signals in standard IRIG formats for distribution and utilization. The instrumentation timing system consists of central time code generation equipment, wire and radio distribution equipment, and timing terminal equipment. The time code generation equipment consists of three IRIG time code generators with automatic comparison and switch-over in event of a failure in the on-line generator. The time code generators are synchronized to Greenwich Mean Time by National Bureau of Standards radio transmissions.

Timing signals are distributed at WSMR by a nine-channel FM time division multiplex system that broadcasts timing to fixed and mobile distribution stations throughout the Range. This radio timing is also utilized by mobile instruments. Local distribution from timing distribution stations is by open wire and cable.



COMMUNICATIONS

The Range Communications System utilizes standard means for the transmission of voice communications, data, timing, missile guidance, destruct, and other types of signals. Communications provide the interconnecting link for information transfer between instrumentation and data centers, Range Control, and Range users in support of test operations. Conventional open wire, cable, switching center and microwave media are used to service specific Range areas.

The real-time data system transmits data from Range instrumentation (AN/FPS-16 radars and project radars) to the IBM 7094/44 computer via a wide-band microwave system.

The ground-to-air communications system consists of 100 watt AM UHF radio transmitting-receiving sets. The equipment is located at the following communications centers: "C" Station, Clark Site, Stallion Site, Salinas Peak, and North Oscura Peak.

The open wire and cable communications plant provides data transmission and voice communications service to over 1100 Range Stations.

Commercial communications facilities are leased for transmission of voice, data, and control signals between WSMR and off-Range sites. Bell Telephone Company TELPAK facilities are in use between WSMR and Fort Wingate, New Mexico and WSMR and Green River, Utah. Individual VF channels with E and M signaling, if required, are in use between WSMR, PMR and ETR for transmission of voice and data.

Ten dial telephone central offices serve WSMR. These are located at Green River, Post Signal Center, Army Blockhouse, Small Missile Range, ALA-5, Rhodes Canyon, Oscura Range Camp, King I, Stallion and Gap Site.

Mobile radio systems are used extensively at WSMR for coordinating efforts of personnel in the field, for obtaining maximum utilization of vehicles and mobile instrumentation stations, and for Range user communications. There are approximately 1200 mobile and 300 base stations.

MICROWAVE SYSTEM

The microwave trunking system consists of links between Salinas Peak and "C" Station, King I, Oscura Range Camp, North Oscura Peak, Stallion Site, Rhodes Canyon, Post Signal Center, Small Missile Range, Launch Complex 38, and the WSMR Cantonment Area.